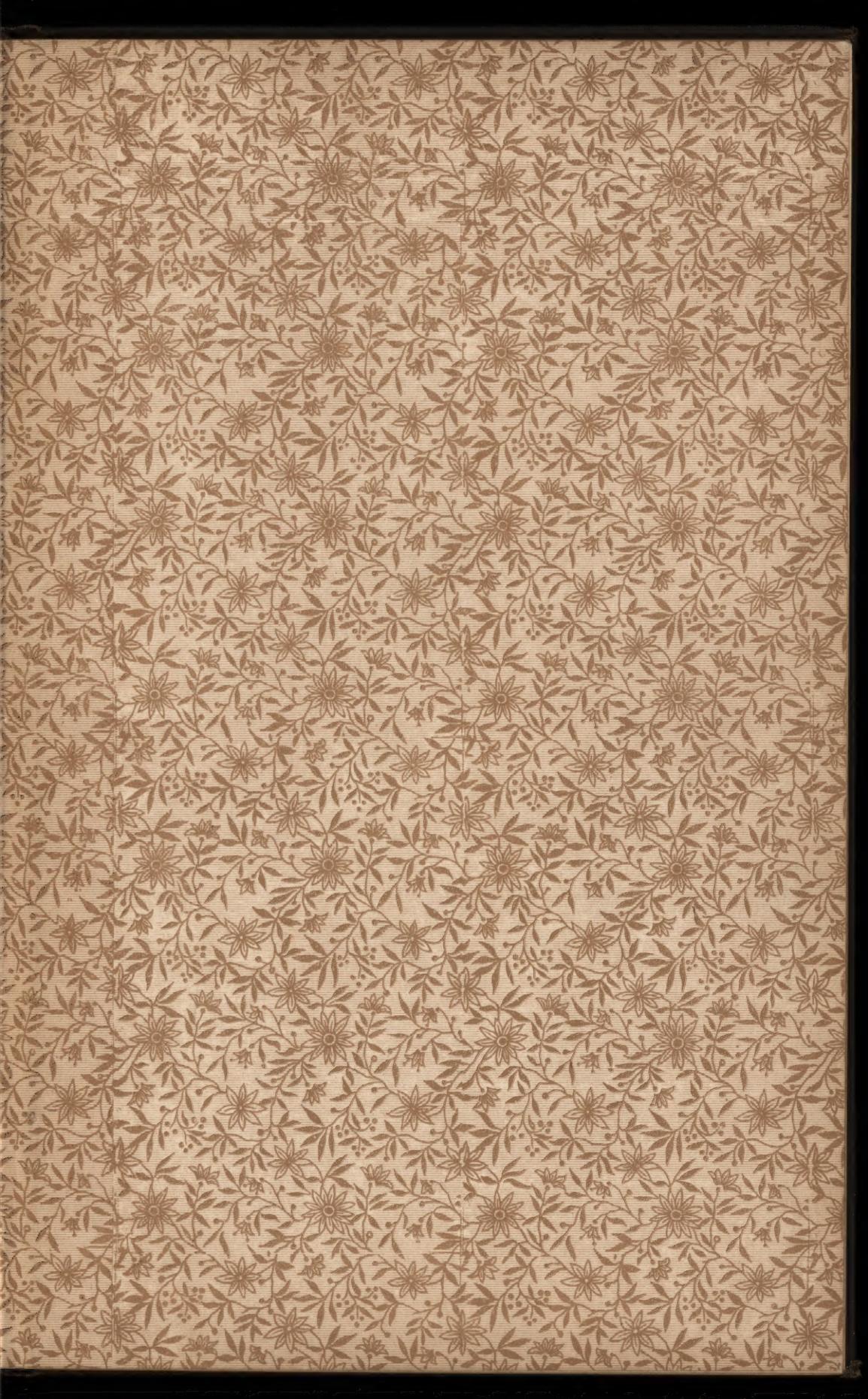
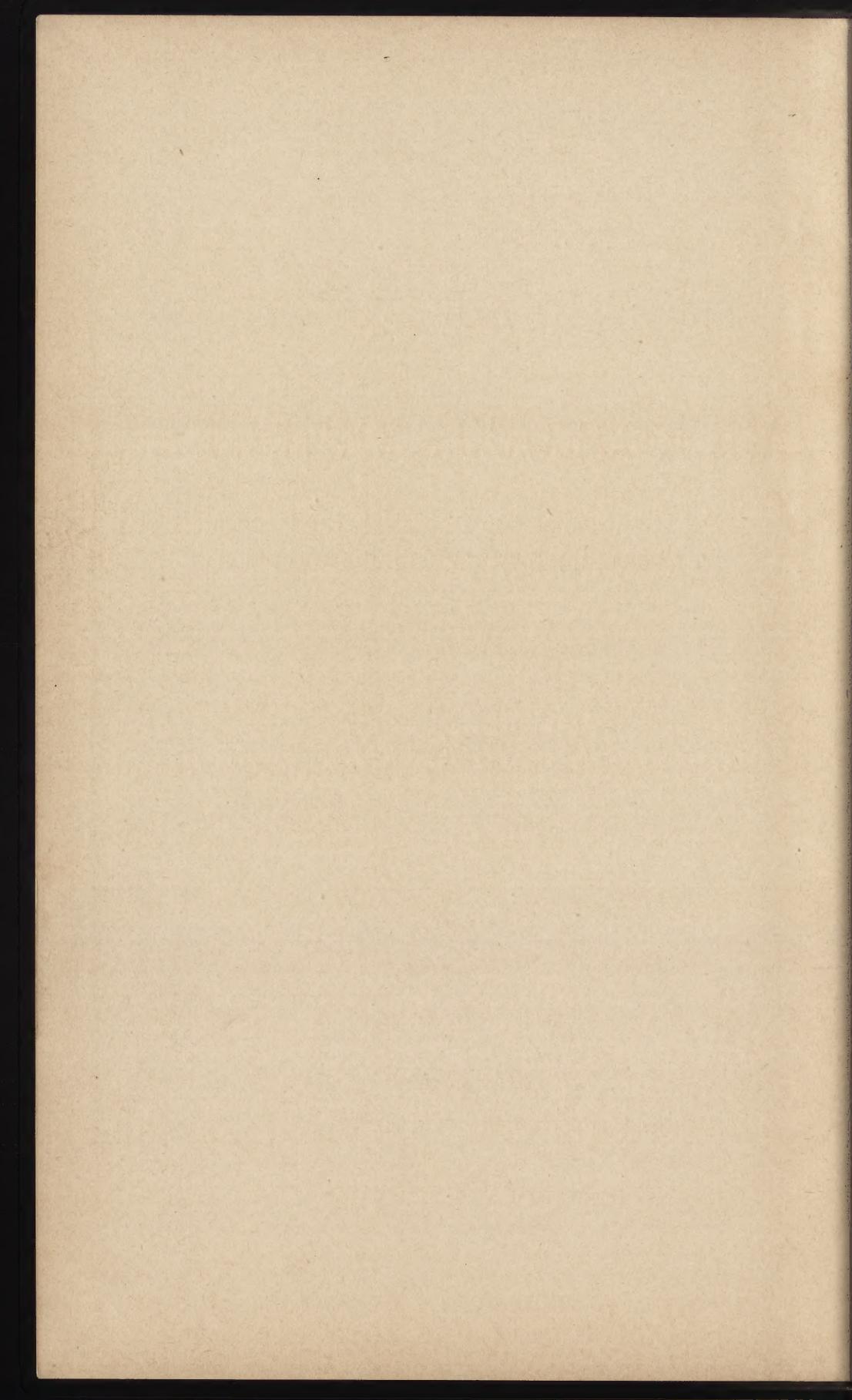


HOW TO PHOTOGRAPH
MICROSCOPIC OBJECTS.







Anthony's Photo Series No. 18.

HOW TO PHOTOGRAPH MICROSCOPIC OBJECTS.

A Manual for the Practical Microscopist.

BY

I. H. JENNINGS.

New York:

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PUBLISHERS' NOTICE.

THE following pages are presented to the practical microscopist as one of the best collections of useful information on photo-micrography that has appeared for many years. The author's standing amongst English scientific workers is a sufficient guarantee for the thoroughness of the methods and processes described, and we feel that American laborers in the same field will find them an invaluable aid in this interesting department of applied photography.

HOW TO PHOTOGRAPH MICROSCOPIC OBJECTS.

BY I. H. JENNINGS.

INTRODUCTION.

Photo-micrography is the art of making, by means of the microscope, photographic enlargements of microscopic objects. Properly employed it forms a valuable tool in the apparatus of the scientific worker, for, by its aid, he can record faithfully the results of the difficult and delicate observations, or delineate the forms of minute bodies concerning whose true structure different observers may vary in opinion. A photo-micrograph allows no room for play of the imagination: it simply shows how a given object appeared at the time the observation was made. Seriously carried out, and more especially when using high powers, photo micrography is hard and trying work. The arrangement of the apparatus, the placing and illumination of the object, are tedious and difficult. Beginners in this fascinating and important art are warned that they must be prepared to encounter not only all the difficulties and troubles incident to ordinary photography, but also others of a different nature peculiar to photo-micrography.

To become a skillful photo-micrographer it is first necessary to be a skilful microscopist; for if the operator does not know how to display an object to the best advantage, his photographs will be useless. Yet the microscopist who comes fresh to photographic operations will find himself in a sea of troubles, spoil a number of plates, produce failure after failure, and, perhaps, throw up photo-micrography in disgust. The writer would advise all who contem-

plate a beginning to first make themselves acquainted with landscape photography and all ordinary photographic manipulation; this need involve little extra expense, and the profit and pleasure to be gained from this course will amply repay any little additional outlay. One of the most skillful photo-micrographers that the writer ever knew was a gentleman who employed the microscope regularly as an instrument of research, but who used the camera only on his holiday trips. Being engaged in writing a paper which required illustration, it occurred to him to try photo-micrography, as the objects which he wished to depict were beyond the skill of the engraver. He did so, and succeeded at once.

Beginners in photo-micrography should bear in mind: 1st. That they should themselves develop every plate they expose; 2nd. That the best results need not be expected unless they are also able to make their own silver prints. A professional photographer may be fit at landscape and portrait work, but this does not show that he is fit to be entrusted with negatives of microscopic objects. To bring out the details of a photo-micrographic negative of a print properly, requires that the operator should thoroughly understand the nature of the object; and this cannot be done except by a microscopist.

All objects are not suited for photo-micrography. Very opaque ones are not the worst, but those which have any strong tint of red, brown or yellow. On this account

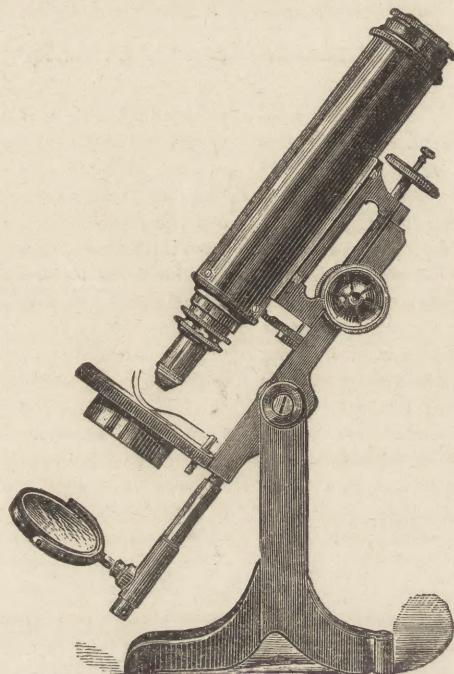
HOW TO PHOTOGRAPH

many beautiful insect preparations cannot be photographed successfully; and we would, therefore, advise the beginner to study the preparation of microscopic objects, so as to be able, in case of need, to prepare and mount his own objects. As an example, a fly's tongue forms a pretty microscopic object, and most of the slides met with are tolerably good; yet a photograph taken from these ordinary slides usually is a

complete failure. The reason is, that the unequal transparancy of the object makes some parts over exposed, while in the darker parts, detail has not impressed the film. Here the best way is to make, or have made, a special preparation.

LESSON I.—MICROSCOPICAL APPARATUS.

Any good microscope stand may be employed for photo-micrography. It must be



really good; an inferior instrument is useless. It must be firmly and solidly built, and the fine and coarse adjustments should be of the best construction. One of the cheap microscopes, with a fine adjustment that gradually moves the object from the field of view on being turned, will be found a source of continual annoyance, and should be avoided. If the student have, by ignorance or ill advice, one of these things, let him part with it at any price, and procure one of the low-priced, but firmly built, well-adjusted stands made by Beck, Collins,

Ross, or Swift. These will be found to give ample satisfaction.

The stand figured above, made by Mr. Collins, of Portland Street, (London,) is well suited to photo-micrographic work. It is well made, takes the full size eyepieces, is furnished with a good one inch and quarter inch, and costs, with case, only £5 10s. A beginner could not have a better instrument. The writer uses a stand by Swift, which has a coarse adjustment so good that a $\frac{1}{2}$ th or $\frac{1}{6}$ th inch may be focussed with ease and precision with it alone. The

shape of the microscope is immaterial; both Ross and Jackson models will give good results if well made. A graduated draw-tube should be obtained, which had best be velvet-lined, to prevent flare. The usual dead black, after a while, wears out of the draw-tube, and renders the microscope useless for photography; thus a more durable material, such as cloth or velvet, should be used to prevent reflection from the sides of the tube.

Several of the continental models, such as Hartnack's, would be useful for photomicrography, from their compact shape and solidity; but their narrow body-tube, which limits the field of view most seriously, and cramped stage, render it advisable to use only English instruments of the latest pattern. If cost be no consideration, then there is nothing to equal one of the large, first-class microscopes of the best English makers, fitted with every possible convenience in stage and sub stage. It is true, an expert manipulator will obtain excellent results with the simplest arrangements; but it is no less true that it is the expert alone who can really appreciate and turn to good account the delicate mechanical contrivances which the skill of the optician has devised for his aid. Thus, a mechanical stage is not absolutely necessary, but it is a great help when working with high powers; and with the very highest powers it is hard to see how it can be dispensed with. The same may be said of the sub-stage; but as this is in some respects more generally useful than the mechanical stage, it should be applied to all microscopes with which an achromatic condenser or paraboloid is to be used. The objections to the tube-fitting usually supplied with student's microscopes are, the difficulty of properly adjusting the sub-stage apparatus, and the very thick upper stage that they necessitate. For photographic work, the upper stage should be as thin as possible, certainly not more than $\frac{1}{8}$ -inch thick, for frequently very oblique light must be employed, and this cannot be done with a thick stage, which cuts off the rays. Using a thin stage and bull's eye lens, it is astonishing how

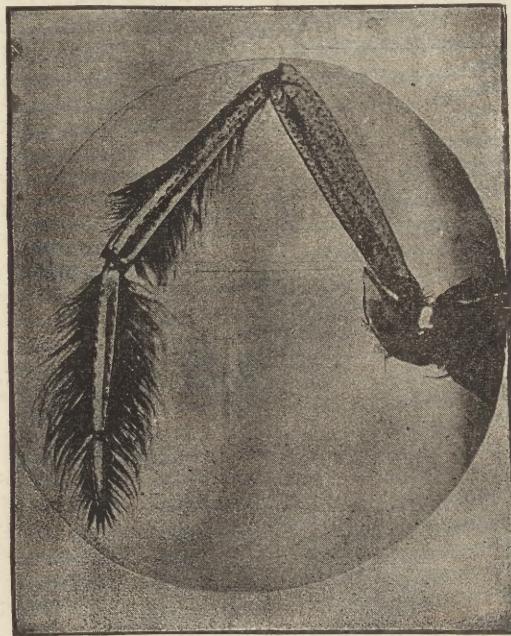
easily a difficult diatom may be resolved, which, with a thick stage, would require the use of an expensive condenser. Most of the English makers now fit their microscopes with thin concentric stages, even when the rack and pinion movement is omitted.

As to lenses, the student is advised strongly to buy the very best, if possible. Let him shun cheap French lenses, more especially the separating lenses, styled "French buttons," which are frequently supplied with £5 or £6 microscopes, and which are only useless rubbish. The stand and lenses should be purchased separately, the latter to suit the requirements of a photo-micrographer. If the very best lenses are too expensive, then purchase some of the cheap low angle lenses, now sold by most good makers, for these, being well corrected up to the angle ascribed to them, are capable of performing a vast amount of real work. The beginner will probably find them much easier to handle than lenses of wider aperture, owing to their greater penetration and working distance; but the more experienced worker will require, especially for photographing very minute objects, lenses of the widest possible angle. Lenses of wide angle admit more light, and have far greater resolving power than lenses of low angle; but they have less working distance; and less penetration. The fact that they almost touch the object, in many cases, when in focus, forms no objection to their use for photography, but it is annoying to have a lens, say a $\frac{1}{2}$ -inch, that will only show the surfaces of objects. This objection, however, can be easily disposed of, by using a contracting diaphragm such as the "Davis Aperture Shutter," made and sold by Mr. Collins, whenever penetration is desired. The use of this shutter renders a lens of widest angle equal to any low angle lens, as far as penetration is concerned; while even with this shutter, the wide angle lens will give superior definition and admit more light than a low angle lens of the same focus.

The choice of lenses will depend, in a great measure, on the photographic work to

be performed. If the beginner proposes to limit himself to the photography of comparatively easy objects, lenses of 2-inch, 1-inch, $\frac{1}{2}$ -inch, $\frac{1}{4}$ -inch, will suffice. A $\frac{1}{4}$ inch of wide angle will be found capable of resolving the majority of test objects satisfac-

tory. A 5-inch or 4-inch will be found very useful for photographing large objects, such as whole insects, wood sections, and anatomical preparations; while if the student requires a few high powers, and cannot afford the expensive ones of the best



LEG OF WATER BOATMAN (*NOTONECTA*).

Taken with a Ross 4-inch.

English makers, he will find the moderate priced immersion lenses of Seibert equal to all the work that will generally be required of them. These lenses are sold by Baker, of Holborn. Immersion lenses are specially useful in photography, as they admit a vast amount of light, and are, therefore, very rapid in action.

Some lenses are not well suited to photo micrography, their visual and actinic foci not being coincident; that is, when an object is focussed accurately on the screen of the camera, and a photograph taken, the picture will be indistinct and blurred, owing to the fact that the rays forming the visual image do not lie in the same plane as those forming the photographic image. Such

lenses *may* be used for photography, by making experiments and determining the amount of allowance for this difference to be made when focussing; but it is far more satisfactory to use lenses which do not require such correction. The writer has used lenses by Ross, Wale, Swift, and Siebert, and the visual and actinic foci were coincident in all such as he has used.

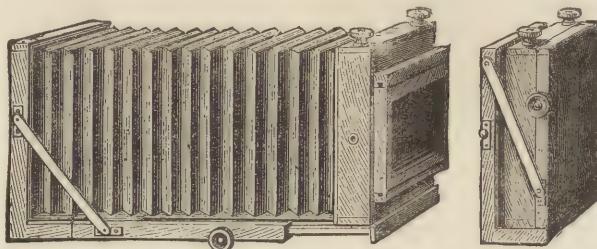
Much difference of opinion prevails as to whether the eye-piece should or should not be used in photo-micrography. Some assert that the eye-piece spoils good definition. This is possible with a bad eye-piece; but the writer has for years used the eye-piece when photographing with low powers, and has found no difficulty in ob-

taining photographs absolutely sharp and well-defined to the very edge of the field. This is also the experience of many other photo-micrographers. In the writer's opinion it is a mere question of convenience; with low powers—say up to $\frac{1}{2}$ inch—the eye-piece may be employed, as the loss of light attending its use is very slight; but with higher powers the loss becomes a serious matter, so it is then necessary to discard the eye-piece, or focussing will be very difficult, and the exposure of the plate inconveniently long.

An achromatic condenser is a very useful piece of apparatus, but may be dispensed with for general work; however, a good one will save much labor and "dodging," when using high powers with difficult objects. A bull's-eye lens accompanies most microscopes, and is really invaluable when the photo-micrographer has learnt how to

use it. For a very oblique light a hemispherical lens is as good as anything. It is attached to the under side of the slide with glycerine, and used in conjunction with the bull's-eye, the best position being found for the lens by experiment. As it will not keep in place unless the microscope be kept vertical, a slip of cardboard should be fastened to the slide below the hemispherical lens, or a little gum may be added to the glycerine. Unless the gum be perfectly white it had best be avoided, as a yellow tint would ruin definition.

The paraboloid and spot-lens are sometimes used in photo-micrography, but even with the most rapid dry plates, dark ground illumination is difficult, and seldom successful. As it, however, shows many objects to better advantage than any other mode of lighting, the student is recommended to see what results he can gain by its use.



LONG FOCUS CAMERA, SUITABLE FOR PHOTO-MICROGRAPHY.

LESSON II.—PHOTOGRAPHIC APPARATUS.

FOR simple photo-micrographic operations, any ordinary camera may be employed. A quarter-plate camera will answer, but the student is advised to obtain a half-plate or even a whole-plate camera, for, as he advances in skill, he will, perhaps, wish to photograph sections of rocks, or woods, or whole insects, on a larger scale than the smaller camera will allow. A good lens will make a half or whole-plate enlargement of an object without loss of definition. Using the eye-piece, and working with low powers, a camera expanding to eighteen inches or two feet will suffice, but for the higher powers, which cannot well be used

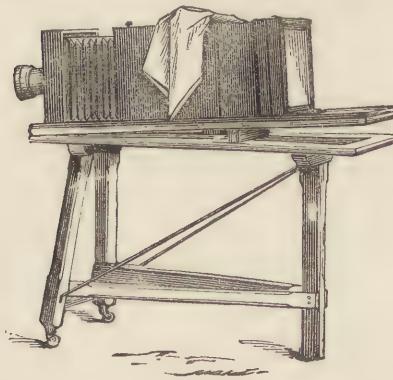
in conjunction with the eye-piece, a camera expanding to four feet, or even six feet, is recommended. The eye-piece cuts off so much light when working with high-power lenses that focussing becomes difficult, if not impossible; while without it, focussing with a $\frac{1}{2}$ th inch or $\frac{1}{6}$ th inch is an easy matter, even when a condenser is not employed.

If an ordinary camera be employed,* there are none better than those sold under the name of "long focus" cameras. The half-plate size expands from three inches to

* Similar photographic apparatus to that mentioned, may be procured of us of our own manufacture.—E. & H. T. Anthony & Co.

eighteen or twenty inches, which is ample for low powers, especially when looking with the eye-piece. The above illustration shows a capital "long focus" camera introduced by Hare, which will answer both for landscape and microscopic work, and forms an excellent companion for the summer holidays, when the microscope will be, or ought to be, laid aside. Even the expert photo-micrographer will find the occasional practice of landscape photography a very good way of "keeping his hands in."

A long copying camera, provided with focussing arrangements back and front, makes a very excellent camera for photo-micrography. It is very desirable that the front should not be fixed to the base-board, but be capable of either sliding back or moving back by screw, for frequently it may be necessary, after all is ready for taking a photograph, either to change the position of the object, or alter the illumination, which can be satisfactorily performed only by looking down the microscope tube. If the camera has to be removed for this purpose, there will be some difficulty in getting everything square again; while if the camera front can slide back along the base-board, the relative position of microscope and screen remains unaltered. Copying

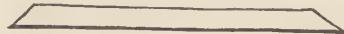


COPYING CAMERA.

cameras suitable for photo-micrography are to be met with in the lists of most dealers.

If the student cannot procure one of these cameras, he may very easily construct one for himself. Procure four boards nice-

ly planed, $\frac{1}{2}$ -inch thick, some inches longer than the proposed camera, and $\frac{1}{2}$ -inch less in width than the bellows are required. Make a long box with the boards, fastening them together at the ends only with screws. Cover this box with thin black calico or book-binders' cloth, pasting the edges together where they lap over. Next cut some slips of thin cardboard $\frac{1}{2}$ inch or $\frac{3}{4}$ -inch wide, and $\frac{1}{8}$ -inch shorter than the width of the box. Cut the corners of each slip at an angle more acute than 45° , thus:



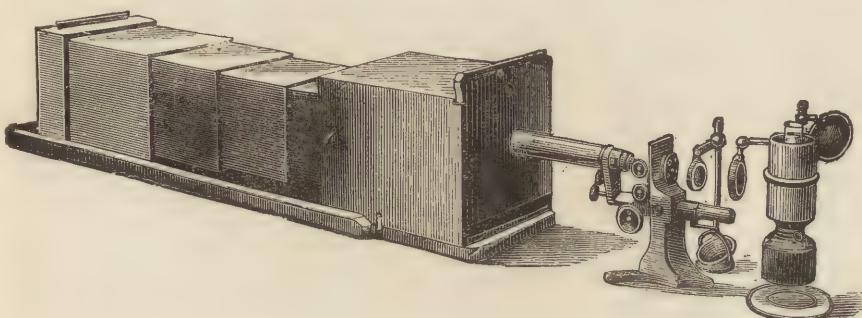
When sufficient have been cut, paste the slips exactly parallel on the four sides of the box, about $\frac{1}{8}$ -inch or $\frac{1}{16}$ inch apart. Each slip must be pasted on with the cut-off ends facing in the same direction. When the paste is dry, put on an outer cover of better material; twilled calico will do, but is somewhat thick for the purpose; good book-binders' cloth is best. The edges should be pasted together as neatly as possible. When the whole is dry, unfasten the end screws, when the boards will collapse, and the bellows can be drawn off. Now proceed to fold it up carefully, by pinching it into shape at the edges of the slips of cardboard, and put the bellows in a copying press, or under heavy weights, for a day or two. The base-board for this bellows should extend in front about 3 feet, so that the microscope and lamp may stand upon it. As the bellows will require no protection, the camera front may consist of a plain vertical board of the right size, constructed to slide back on the base-board about 15 or 18 inches. The dark slide should be purchased preferably a single one, and the back of the camera made to fit it. The camera may be opened or closed by hand alone, the back moving in guides screwed along each side of the base-board; or by endless screws cut with a rather coarse thread. When the endless screw is not used, a screw and butterfly nut must be employed, to clamp the camera in any desired position.

If the student has not sufficient hand skill to construct a bellows camera he may

make, or have made the simpler arrangement represented below. As will be seen, it consists of a series of boxes fitting into each other after the fashion of a sliding body camera. It can easily be lengthened or shortened by the addition or removal of one or more boxes. Any joiner could easily construct such a camera on seeing the illustration.

Double dark slides may be employed, if well made, but a single slide is better, as the focussing glass can be placed in it, and when replaced by the sensitive plate the latter will lie in exactly the same place, which is of vital importance. For low powers, very fine ground glass will answer, but for higher powers plain glass is best.

In this case the image must be examined by means of a focussing eye-piece. The following excellent mode of performing the difficult operation of focussing is given by Mr. G. E. Davis, in "Practical Microscopy :" "Removing the ground glass slide, another is substituted of mahogany, but pierced with a series of seven holes, into each of which the ordinary A eye-piece may be fixed. The thickness of the slide is such that when the eye piece is pushed in as far as it will go, the diaphragm lies in the same plane as the ground surface of the glass slide. To anyone accustomed to focus by the old method, the present system will be found a considerable improvement, it being easy under these conditions to obtain a



sharp focus with an ordinary paraffine lamp when using the $\frac{1}{6}$ objective."

When the camera is extended only a short distance, the hand will be able to reach the coarse or fine adjustments of the microscope; but when drawn out to three feet or four feet, this will be impossible. It then becomes necessary to provide some method by which focussing can be easily and exactly performed while viewing the image on the screen, the camera being extended. Procure a hollow brass rod, $\frac{1}{8}$ inch in diameter, and the length of the base-board. Fix it to the side of the board by metal "eyes," so that the rod may revolve somewhat stiffly; if the camera be supported on trestles, the rod may be fixed under the base-board, which is more convenient. Make a grooved wooden wheel, two inches diameter, and fasten

it to the rod, so that it will be opposite the fine adjustment of the microscope when the latter is placed horizontally, with the eye-piece end fitted to the camera front. Make an endless band of narrow tape, of such a length that it will pass over the grooved wheel and the fine adjustment rather tightly. On turning the extremity of the rod, the fine adjustment will be moved with sufficient slowness and accuracy to allow of correct focussing with a lens of high power. The writer has long used an arrangement of this sort when photographing diatoms, and found it answer admirably.

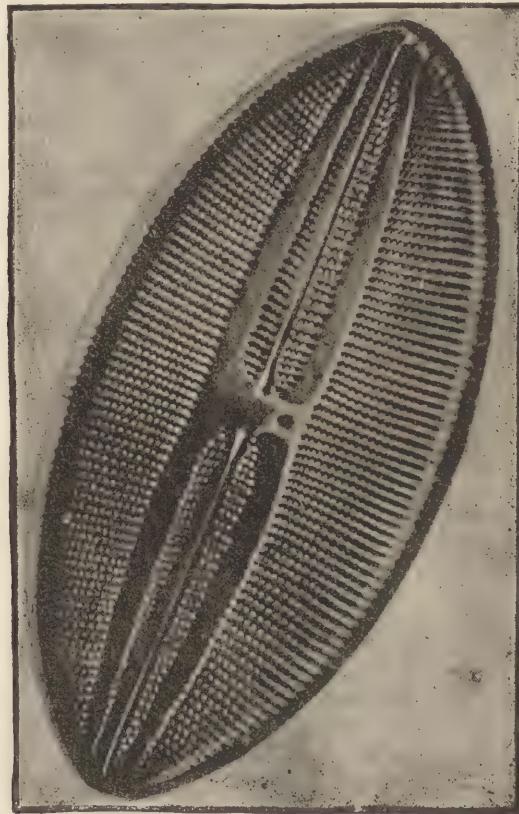
The remaining photographic apparatus will be as follows: A macintosh focussing-cloth; ebonite or glass dishes for developing and fixing negatives; glass measures, say 2-oz., 4-oz., and 6-oz. capacity; basins

for washing negatives; a porcelain dish for toning prints, and another for fixing them. Racks may be used for drying the negatives, but in winter, standing them up on a warm mantle-piece is as good a plan as any, unless the plates be made with very soft gelatine, when catastrophes may be expected

in the shape of distortion of the image, or even melting of the gelatine.

LESSON III.—ILLUMINATING APPARATUS.

In this country photo-micrography by daylight is troublesome and unsatisfactory. The sun shines brightly during so few



NAVICULA LYRA, X 900.

Taken with a Siebert's $\frac{1}{15}$ immersion: Exposure about fifteen seconds to magnesium ribbon in a holder.

months of the year, and is so fickle when he makes his appearance, that the photo-micrographer is compelled to fall back on artificial light to do his work. In many respects sunlight would be preferable, were it only always at the command of the photo-micrographer; it costs nothing, is rapid in its action, is more powerful than any other

light, and exhibits objects illumined by it as we are accustomed to see them. The chief disadvantage of using the sun as a source of light is, that, owing to the earth's motion, the direction of the light is continually altering, necessitating the use of an expensive reflecting instrument, called a heliostat, to keep the rays constantly in any required direction.

The use of artificial light has been condemned by many. One photo-micrographer even goes so far as to say "artificial light is a delusion;" but on comparing results we shall find that, at least since the advent of rapid dry plates, photo micrographs have been taken by many workers fully equal to any produced by daylight. In fact, certain photo-micrographers who have most strongly advocated the use of sunlight, have not produced work even equal to that which may be done by any manipulator of moderate ability with artificial light after a few months' practice. Artificial light is much more easy to manage than daylight, and does not vary so much in actinic quality; hence exposures are easy to calculate, and the illumination is more completely under control.

The light given by burning magnesium is the richest in actinic rays. If the student possesses a Solomon's magnesium lamp, he will find no difficulty in working with this light, the only objection to the lamp being that it consumes the magnesium rather rapidly, and thus becomes too expensive to be used constantly. It may, however, be used with great advantage when photographing very minute objects with high powers. The most economical mode of using magnesium ribbon is to burn it in a holder made of tin or brass tube, the bore being just large enough to admit the easy passage of the ribbon. The tube should be about six inches long, and mounted on a stand similar to that of the bull's-eye condenser, with joints to admit of proper adjustment.

When using the holder, a spirit lamp should be placed opposite the achromatic or other condenser, and the magnesium holder placed in such a position that when the ribbon is thrust through the tube it may enter the flame of the spirit lamp. Some difficulty may be experienced in getting the ribbon to properly illuminate the screen, but a few experiments will render the matter easy. The writer has made considerable use of the above simple apparatus, and very satisfactorily; but as it necessitates two manipulators—one to attend to the light while focussing and arranging the

correct position of the light, and another to superintend the screen and focus—he much prefers, for all purposes, a good paraffine lamp.

A well-made lamp is necessary, but good paraffine still more so. Avoid all low-priced, strong-smelling oils. Paraffine sold at 8d. per gallon is not only unfit for photo-micrography, but absolutely dangerous. When burnt in any lamp with a large wick it begins to evaporate rapidly as soon as the lamp gets warm, and after a while the flame will rush up the chimney, blackening it, perhaps cracking it, and frightening the operator, if doing nothing worse. Reliable paraffine may be had at 1s. 6d. per gallon, and this will give more satisfaction in every way. Duplex lamps may be used, but they present no advantages for photo-micrography. They give out much heat, consume a large quantity of oil, and the double wick is troublesome when using high powers. A single wick is far preferable, but it should be the broadest possible to obtain.

The lamp devised by Mr. Dallinger specially for working with high powers, is, perhaps, the very best yet made; but photographs can be taken with any paraffine lamp. For some time the writer used a tiny microscope lamp, and took some very successful photographs with lenses varying from 2 inches to $\frac{1}{8}$ th inch, but the exposure was necessarily long with all of them. The object of the photo-micrographer should be to make his exposures as short as possible, and this can only be done by using a powerful lamp and a vigorous developer.

The light from a broad-wick paraffine lamp will be found sufficient for even high powers, but the brilliancy of the light may be much increased by putting a lump of camphor in the bowl of the-lamp. Gaslight and candle-light are far too unsteady to be used for photo-micrography.

LESSON IV.—EXPOSING THE PLATE.

No rule can be laid down as to the duration of the exposure. It depends (1st) on the focal length of the lens used; (2nd) its aperture, wide-angle lenses being far quicker than those of low angle; (3rd) the na-

ture of the light used; (4th) the nature of the object, yellow and brown objects always requiring a prolonged exposure; (5th) the development. An operator who uses a weak developer will always expose his plates for an unnecessarily long time. The beginner will perhaps think the exposure the most difficult part of photo-micrography, but as he progresses he will alter his mind, and think the proper illumination of the object far more difficult.

Using a good paraffine lamp, and lenses of from 5 inches to $\frac{1}{16}$ -inch, the exposures may vary from a fraction of a second to

half an hour. For instance, the larva of a flea, a very transparent object when properly illuminated, will not require more than half a second with the 2-inch objective, while with the same lens a section of coal may require twenty minutes. The section of Alveolina limestone figured below, although of a white color, and apparently very transparent, had an exposure of fifteen minutes. As a rule, all rock sections will require a rather long exposure, as they stop a large amount of light. All sections should be as thin as possible; yet a good color is of more importance than thinness. The



SECTION OF ALVEOLINA LIMESTONE, HERAULT, BELGIUM.

writer has a section of a tertiary limestone from Bengal, of a strong yellow color, which he has often vainly tried to photograph satisfactorily, although the section is most admirably cut, and very thin.

The wing of a midge, here shown, will serve as a good example of a very transparent object, which yet has plenty of detail. This object had an exposure of one second; less would have sufficed with a more powerful lamp.

High powers, being used chiefly with very transparent objects, do not require the tremendous exposures that people generally

imagine. A $\frac{1}{16}$ -inch, when properly illuminated, will give a good clear image on the focussing screen five feet away from the object. When the writer first began using high powers, he heard such exaggerated statements about the difficulty attending their use, and the long exposures they required, that on first trying *P. angulatum*, he gave an exposure of an hour to this transparent object. On developing, the plate came out almost clear glass; only a faint ghost of the object could be seen on the plate. A subsequent exposure of fifteen minutes, under the same conditions,

gave a fair negative. All objects are not fitted for photography; therefore it may be taken as a rule that if any object bears an exposure of half an hour with any lens, without being fully exposed, it is simply useless to attempt it. There is a little scarlet mite common in gardens, the scarlet Trombidium, which, owing to its color, may be exposed for any period without getting any better photograph than a blank

outline. Such objects should, if possible, be bleached before attempting to photograph them.

When magnesium ribbon is used as the source of light, the exposures become very rapid. The writer has never used this light with low powers, but he has found ten seconds to fifteen seconds ample for diatoms with the $\frac{1}{16}$ -inch objective.

The dry plates recommended for photo-



WING OF MIDGE (PSYCHODA).

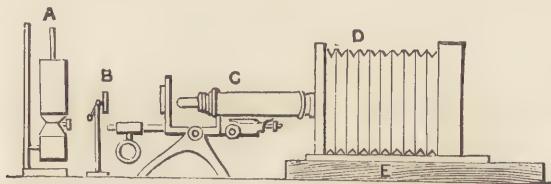
micrography are the most rapid in the market. The writer has used Swan's ten times collodion, and thirty times collodion; and while the ten times are excellent for low powers, he still prefers the thirty times plate for every purpose. He has also used plates still more rapid, and found them satisfactory in every way. Very rapid plates are often difficult to manipulate when used for landscape work, but when used for pho-

to micrography they become as easy to develop as any slow plate, while they have the great advantage of increased rapidity. The writer is not alone in advising the use of rapid plates, for the author of *Practical Microscopy* has obtained good results on Swan's fifteen times plate, while Dr. Sternberg, one of the most experienced and accomplished of living photo-micrographers, uses Eastman's instantaneous dry plates.

The maker of the plates is of little importance. The writer has tried most of the makes in the market, and has got good results with all. The chief thing is that the plates be made of good hard gelatine. If a sample of plate be found to be pre-

pared with soft gelatine, reject it at once. Frilling may be laughed at, but shrinkage of the film is simply ruin to all good work.

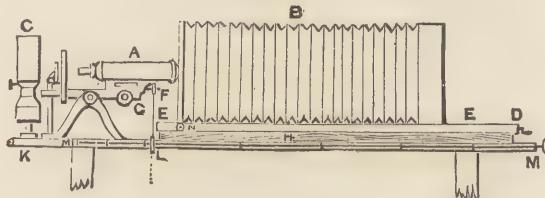
We come now to the actual exposure of the plate in the camera. First place the object on the stage of the microscopes



ARRANGEMENT OF MICROSCOPE WITH SHORT CAMERA FOR USE WITH EYE-PIECE.
A, lamp; B, condenser; C, microscope; D, short camera; E, block to support camera.

choose your lens, and bring the object into focus. Notice carefully the chief points that you wish to be shown clearly in the photograph, that special attention may be paid to them in focussing and exposing. Then lay the microscope in the horizontal position, place the lamp in front, and adjust the illuminating apparatus in the best position. The object may be seen best with oblique light: in this case be very

careful, or the plate may not be fully illuminated, when the negative would be rendered worthless. When the illumination has been satisfactorily adjusted, draw the front of the camera up until the eye piece of the microscope fits in the hole made for its reception. A hood of black velvet will probably be necessary to render the connection of camera and microscope light-tight. This done, view the object on the



ARRANGEMENT OF MICROSCOPE WITH LONG CAMERA WHEN THE EYE-PIECE IS NOT USED.

A, microscope, B, camera; C, lamp; D, winch screw; E, base-board; F, fine adjustment; G, band connecting F with wheel of rod, L; H, block supporting camera; K, table; L, wheel of focussing rod; M, focussing rod; N, rack and pinion for moving camera front.

screen, which will be very indistinct. If the adjustments of the microscope are within reach, by their means slightly withdraw the lens from the object until the latter is in good focus. If the eye-piece be removed, and the adjustments are, therefore, out of reach by reason of the length of the camera, turn the focussing rod until a satisfactory focus be obtained. When this is accomplished, leave the apparatus for a few

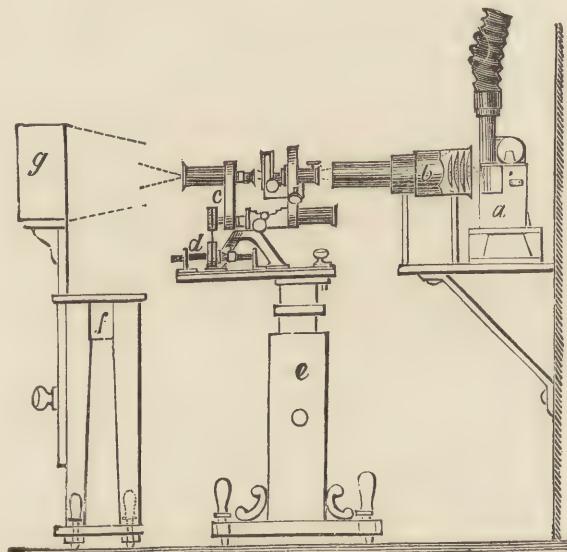
minutes to allow of its expansion from the heat of the lamp. With low powers, this expansion is hardly likely to affect the results, but with high powers is very injurious.

Sometimes, in fact, when using a high power, the expansion of the metal parts of the apparatus during a long exposure may be so great as to throw the object quite out of focus. It is thus advisable to place the lamp as far away from the microscope

as possible, consistent with suitable illumination. The writer frequently uses a cardboard screen between the lamp and microscope, with an aperture to allow the rays to pass through. By this means the microscope is kept cool, and possible injury to the lens and object averted. The alum cell, used with the heliostat to stop the heat rays, can hardly be used successfully with lamplight. Sometimes, however, a thin cell, containing ammonio-sulphate of copper, may be employed when photo-

graphing very transparent diatoms, and answers the double object of keeping off the heat from the lamp and giving a more diffused light. For the latter purpose, with low powers only, a strip of fine ground glass or oiled paper may be placed beneath the object. A slide of blue glass, 3 inches by 1 inch, is also used by some operators for softening the light.

All being ready for an exposure a blackened card must be placed opposite the lens, or below the stage, to cut off the light



a, Magnesium lamp; *b*, condensers; *c*, microscope; *d*, focussing rod attached to fine adjustment; *e*, support of microscope; *f*, support of focussing-screen *g*, and moving backwards and forwards in a line with the microscope, either in guides or on rails; *g*, focussing-screen.

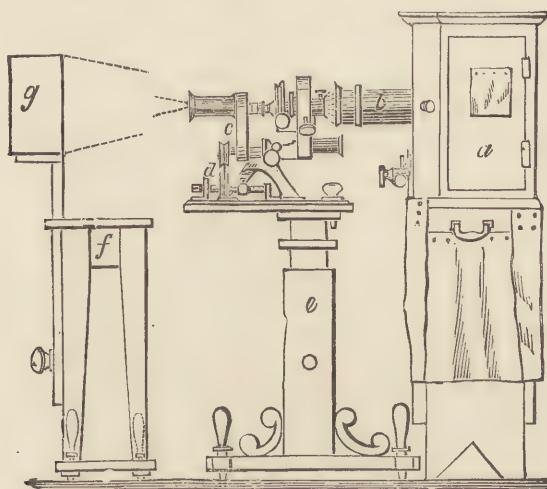
With a low power, the card should be in front of the lens. The dark slide may then be inserted, and the shutter drawn up. After waiting for a few moments to allow all vibration to cease, the card in front of the lens must be rapidly removed. During the exposure the operator must abstain from walking about the room, for the vibration so produced would injure the sharpness of the picture, more especially with low powers and short exposures. When the exposure is deemed sufficient, the blackened card

must be replaced in front of the lens, and the shutter pushed down. If other exposures are to be given, do not turn the lamp down, but leave the flame the full height, until the next plate can be inserted in the camera. In this way the alternate expansion and contraction of the microscope, etc., is avoided. If, on developing, the first negative be found either over or under-exposed, try again, without disturbing the apparatus.

This and the former figure illustrate the

method adopted by some workers of using the microscope in a dark room, and thus dispensing with a camera. If the student have sufficient room at his disposal, and can fit up an apartment especially for his

work, perhaps this arrangement is the very best that can be used; it is, however, hardly suited to beginners. The references to each figure will suffice to explain the general arrangement of the apparatus.



a, Electric light apparatus : an incandescent lamp might be substituted with advantage. The other letters same as in the figure preceding.

LESSON V.—DEVELOPMENT.

The development of a photo-micrograph does not differ much from that of other negatives, but requires somewhat more patience, as the image on a properly exposed plate is usually slow in appearing, and must not be "forced" in any way. Any ordinary dry-plate developer may be used, but the writer has found that known as the sulphite developer answers best.

Ferrous oxalate is recommended by some photo-micrographers, notably by Dr. Sternberg, but is hardly sufficiently "elastic" to satisfy all requirements. It has the great merit of being clean and simple, while it never stains the negatives, as some preparations of pyrogallic acid do; but the operator will find that with this developer he has very little control over the development. In fact, the development is so mechanical that some operators, like Dr. Sternberg, are content to place the plate in the solu-

tion and let it take its chance. No one who has become used to pyrogallic acid will ever care to use ferrous oxalate, and the writer would not advise the beginner to use it, but at once to master the difficulties of pyrogallic acid and ammonia.

However, as some may prefer to try what can be done with ferrous oxalate, the formula for this developer is given here :

Saturated solution of ferrous sulphate,	1 part.
Saturated solution of potassic oxalate,	3 parts.

The potassic oxalate should be neutral, but, as it frequently is alkaline, a few crystals of oxalic acid may be added, until the solution is neutral to test paper. The ferrous sulphate should be added to the potassic oxalate, not *vice versa*. A solution of potassic bromide, 20 grains per ounce, should be kept at hand. A few drops of this will be

useful to add to the developer in case of over-exposure.

The developer which the writer prefers, and which he has used successfully for all sorts of work for some years, is the following :

A.—Pyrogallic acid,	. . .	$\frac{1}{2}$ ounce.
Sodic sulphite,	. . .	1 "
Water,	40 ounces
Citric acid,	. . .	1 dr.
B.—Liquor ammoniæ,	. .	$\frac{1}{2}$ ounce
Potassic bromide,	. .	40 grains.
Water,	40 ounces.

These form stock solutions, and will keep indefinitely. Both had better be kept in stoppered bottles. The sodic sulphite must be good ; otherwise, good results need not be expected. Some writers have stated that sodic sulphite produces green fog, but this is hardly correct. The writer had used the sulphite developer for over two years before he saw anything of green fog. He had been accustomed to buy his chemicals from a good chemist, and had always paid 1s. 6d. per pound for sodic sulphite. Happening once to require some immediately, he purchased a sample from the nearest shop, and paid 6d. per pound for it. It was wretched looking stuff, but he made it up. On developing, every plate was covered with a glorious sheen of green fog. Happily, this was completely got rid of by applying Mr. H. Farmer's solution, which will be described further on. *Moral:* Buy the best chemicals from a good chemist, and do not grudge the price paid for them.

Another modification of the pyrogallic developer is given by Mr. S. Fry, as follows :

A.—Acid pyro,	1 ounce.
Saturated acid solution of sodic sulphite,	. .	12 ounces.
B.—Ammonium bromide,	300 grains.	
Ammoniæ liquor,	. .	2 ounces.
Water,	12 ounces.

Take 1 ounce of A ; put it in a 20-ounce bottle, pouring on it 15 ounces of water. Do the same with B. Use equal parts for developing.

To develope a plate, proceed as follows : Have a good sized lamp glazed with pale red glass, not with the black abomination generally called "ruby," which is almost opaque to light. A good lamp may be made from any kind of box, by fitting to it a sliding pane of red glass in place of the lid, and putting a small paraffine lamp therein. A chimney should be made at the top, to ventilate the box. This arrangement will give a flood of light without endangering the plate. The writer always develops close up to the lamp, and has never yet fogged a plate. If the operator cannot see what he is doing, he need not expect good negatives, but may reasonably look for indications of failing eyesight after a few months' work. So, to get good negatives, and save temper and eyesight, have plenty of light of the right sort. No light is really non-actinic, and much of the "ruby" glass in use is quite as unsafe to use as the yellow glass used in developing wet collodion plates. Yet, once in the developer, even yellow glass may be used with complete safety. It is only while the plate is dry that exposure to a strong light is likely to act injuriously. Thus in changing plates, or in taking them from the slides to develope, let the lamp be shaded or turned down ; but while developing, every detail must be clearly seen.

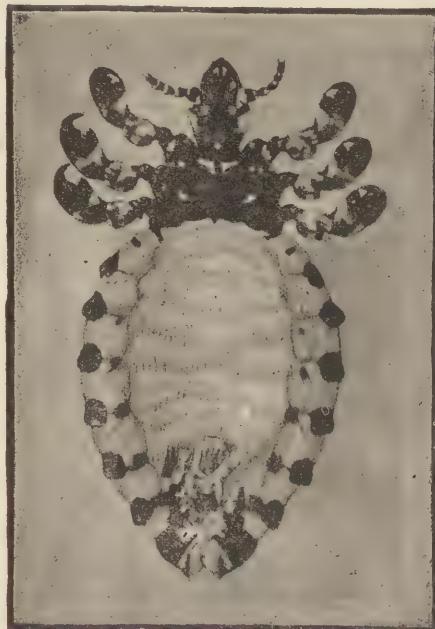
To proceed. Place the developing dish near the lamp ; pour into the developing cup, for a half-plate, 1 ounce of the pyrogallic solution, and $\frac{1}{2}$ -ounce of the ammonia and bromide. Place the plate in the dish, and pour over it the mixed solutions. If the image runs out rapidly, pour the developer off, and make up a fresh developer of 1 ounce pyro, and 1 dram ammonia and bromide. If, after this, the detail does not come out satisfactorily, pour the developer back in the cup, and add more ammonia. By varying this mode, plates that have received thirty times the correct exposure may be satisfactorily developed. They will hardly have the brilliance and "pluck" of a properly exposed negative, but will yield fair prints.

If the image does not make its appear-

ance after it has been in the developer about a minute, add the remaining $\frac{1}{2}$ ounce of the ammonia solution. The image will then slowly appear, if the plate has been properly exposed; but if under-exposed, only further doses of ammonia will bring it out. In the latter case, take no further trouble with the plate, but at once expose another, for an under-exposed plate is simply useless.

It will be found in developing some negatives that one part will develop more read-

ily than another, and become so dense as to be quite unprintable. The photograph given below (parasite of ox) is an example of this. On developing, the body appeared first, and became of an alarming blackness before the legs had got little more than their outline. The developer was at once thrown off, and the negative well rinsed in water. Fresh developer was made up, and the tray tilted up, so that when the negative was again placed in the dish the developer would cover the parts only partially



PARASITE OF OX. 2-inch obj.

developed, which in this case were the head and legs. The dish was gently rocked all the time, and the negative, when finished, was of uniform density. By this means the after reduction of the negative was avoided.

If the development proceed satisfactorily, don't be in any hurry to take the plate from the developer; over-development will not do much harm, while the contrary would ruin it. When all the details are well out-examine the plate, by holding it up before the lamp. Should it prove sufficiently

dense, rinse it in water, and place it for a minute in a solution of alum and citric acid; wash again, and put it in another dish containing hyposulphite of soda made up thus:

Hyposulphite,	4 ounces.
Water,	20 "

When the creamy bromide of silver is dissolved, which may be known by the plate becoming quite clear and transparent, place the negative in fresh hyposulphite for a few

minutes; no fear need be entertained of the hyposulphite solution *weakening* the negative. Then put the plate in running water for half an hour. This will be sufficient, but any trace of hypo. will be got rid of in the next bath:

Alum,	2 ounces.
Citric acid,	1 ounce.
Water,	20 ounces.

This solution will also harden the film, and render it less liable to injury from scratches or wet. The final immersion in alum should be regarded as absolutely necessary. It will brighten up the negative, removing any stains which the developer may have left, and make it "quicker printing."

The negative should not be dried too rapidly. In fine dry weather it can be best dried by placing it out of doors. In winter time, the writer stands his negatives on a warm mantel-piece, where they dry in one or two hours. The only precaution to observe is, that the plate should have previously been soaked in the alum bath for at least five minutes; otherwise, if the film be composed of soft gelatine, the heat of the mantel-piece is apt to melt it.

LESSON VI.—DEFECTS IN THE NEGATIVE.

As the defects in photo-micrographic negatives are very numerous, it may be well to mention the chief, and their remedies, when such exist.

1. *Unequal Illumination.*—This is very apt to occur when using very oblique light, but may happen also with central light, from improper arrangement of condensers, etc. This defect may be known by the negative being dense on one side of the plate and thin on the other. Do not blame the plate maker for improperly levelling his plates; this defect sometimes occurs, but very rarely. If the difference of density on each side is not very marked, it may be remedied by using matt varnish on the thin side of the plate, to diffuse the light when printing. Adding a little yellow dye to the varnish often improves the result, but in all cases the rough edge of the varnish should be softened by the use of a little alcohol or ether, or a nasty mark will be left on the

print, just under the boundary line of the varnish.

2. *Too Powerful Illumination.*—In this case the object is "drowned in light," and the picture comes out flat and degraded. Remedy: take another negative.

3. *Reflection from the Apparatus.*—When the tube of the microscope is not lined with cloth or velvet, a bright central spot may often be seen on the screen while focussing, and a corresponding black patch will be found on the negative, which will be worthless. When using the eye-piece this defect will not be met with. Reflection from the camera will also ruin the negative; also using the eye-piece without the cap. Let the inside of the camera and microscope tube be a dead black.

4. *Access of Stray Light to the Plate.*—Probably through the connection of camera and microscope not being light tight. Result—general fog. Use a thick black velvet hood to connect the microscope with the camera, and keep it in place with elastic bands.

5. *Green Fog.*—This may arise from the use of impure sodic sulphite, or, in the plain pyro. developer, from using too much ammonia. Green fog appears to be a silver deposit, from the fact that certain silver solvents get rid of it at once. Bichromate of potash, or peroxide of hydrogen, may be used, but the writer recommends the following, which is given by Mr. Howard Farmer in the *Year-Book* for 1884:

- A.—Potassium ferricyanide, 1 ounce.
Water, 20 ounces.
- B.—Sodium hyposulphite, 1 ounce.
Water, 20 ounces.

First wet the negative if it has been dried, pour a little of the hypo. solution in a cup and add a few drops of the ferricyanide solution. Dip a plug of cotton-wool in this mixture, and sponge the negative rapidly with it; then plunge it in water, and wash well. All trace of green fog will have disappeared.

6. *Over-exposure.*—This should be controlled in the development. After-intensification rarely produces even tolerable negatives from over-exposed plates. If much

over-exposed, don't waste time in trying to patch up the negative, but expose another plate.

7. *Under-exposure.*—There is no cure for this evil: destroy the negative and take another.

8. *Under-Development.*—An under developed plate is useless. Don't hurry the development, but be sure all possible detail has been worked out, and examine the negative for density before the lamp.

9. *Thickness*—The negative appears fully exposed and developed, but is too thin to give good prints. In this case try the effect of covering the back with matt varnish, and print in the shade. Never intensify a negative before trying how it will print. Many a negative that appears too thin will give perfect prints. The negative from which the accompanying illustration of "Palpi of Male Spider" was taken furnishes a good example of this. This nega-



PALPI OF MALE GARDEN SPIDER.

tive appears a mere "ghost," but prints well and strongly. Had it been intensified it would probably have been ruined. If the matt varnish does not mend matters, the negative must be intensified. There is a choice of intensifiers, but the mercury and silver intensifiers are most generally used. The mercury intensifier is made as follows:

A.—Saturated solution of mercuric chloride.

B.—Liquor ammonie, 10 drops per oz. After soaking the negative in water, it is placed in the bichloride solution until it becomes uniformly white. If requiring only slight intensification, it must be left in only a few seconds, or it will become too dense. Then wash well for five minutes, when the negative must be placed in B, which will turn the plate to a dark color. With a little experience, this intensifier will be

found very useful, but all intensification should be avoided if possible. Look for good results to the development alone, and let intensification be merely a last resource.

Other intensifiers are potassium sulphide and ammonium sulphide; either salt may be made up to the strength of 1 dram to 20 ounces of water.

One of the best silver intensifiers is that given by Mr. W. Brooks, and is as follows: "After the plate has been well washed from the hypo, place it in a weak solution of alum and citric acid solution:

Stock Solution.

Saturated solution of alum, 10 ounces.

Citric acid, 1 ounce.

For the solution above named, I dilute one part to four of water, allow the plate to remain in it about five or six minutes; in the meantime, place in a developing cup about (say for a small plate) two drams of the stock solution of alum and citric, and place in it about four grains of pyro.; when dissolved, add a few drops of about a twenty-grain nitrate of silver solution."

This solution is to be applied to the plate until sufficient density be obtained; when the plate is washed, it is placed in the hypo. bath for a few minutes, again washed, and finally treated with alum and citric acid solution to clear it. Plates thus intensified should not first be dried.

10. *Too Great Density.*—This is more frequently met with when using the plain pyro. developer. Perhaps the simplest agent for removing it is Mr. Howard Farmer's ferricyanide reducer given above in speaking of green fog. The plate, if dry, is soaked in water for a few minutes, then placed in the solution, and examined from time to time until sufficiently thin. Only a few drops of ferricyanide must be added, or the action will be too rapid. Then wash well in running water, and dry.

11. *Shrinking of the Gelatine.*—This may arise from the gelatine being too soft, or from heat being employed to hasten the drying, which is a great mistake. The shrinking may be slight, spoiling the fine microscopic detail, or may amount to actual

distortion of the image. Either way, the negative is ruined; the photo-micrographer is therefore advised to use only plates prepared with hard gelatine. Since the use of the alum bath has become more general, frilling is not so common as formerly, and the photo-micrographer need hardly be cautioned against it. Still, to avoid this, as well as the more serious evil of shrinking of the film, any plates found to be prepared with soft gelatine should be rejected for microscopic work.

LESSON VII.—PRINTING.

The advice given in the introduction is here repeated: let the photo-micrographer make all his own silver prints, as in no other way can he hope for results of a satisfactory nature. The process is not difficult, and, when once mastered, the microscopist will have the pleasure of seeing his pictures *real* representations of the originals, instead of being little else than caricatures, which is often the case when the negatives are entrusted to another to print. A professional photographer may be able to produce perfect specimens of art from portrait or landscape negatives, yet fail entirely when he tries to print a photo-micrograph, simply from not understanding the nature of the object represented.

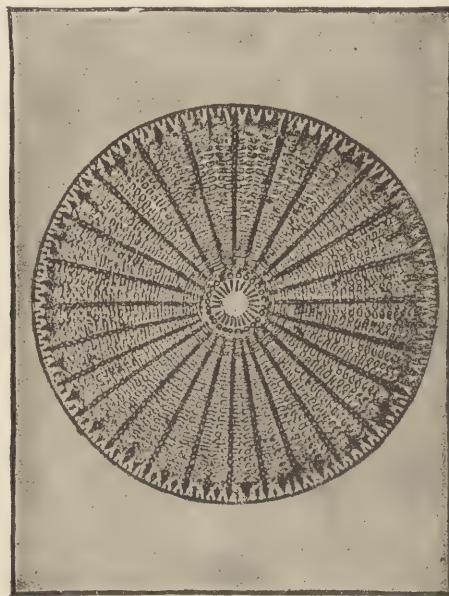
Ready-sensitized paper may now be procured of great excellence at a moderate price. The photo-micrographer should purchase the best obtainable, for the best costs at first very little more than the worst, and in the end costs really less, as there will be no defective sheets to reject, to say nothing of the superior quality of prints to be produced on good paper.

Frequently a photo-micrographic negative may require some little preparation before it is ready to print. For instance, diatoms being, as a rule, very transparent objects, require a short exposure. This exposure, though sufficient to bring out the detail in the diatom, is not long enough to give proper density to the background, which should appear white in the finished print. In this case the best plan is to "paint out" the background, at the back

of the negative, with Bates' or Fallowfield's black varnish. It will be easy to follow with the brush the regular outlines of the diatom; but should any varnish trespass on the edges, don't wipe it off, but let the whole dry. When dry, hold the negative up to the light, and go round the edges of the image with a fine pointed penknife cutting away in an even manner any varnish that intrudes on the edge of the picture. The varnish should come exactly up to the edge of the image; there should be

no intervening space, or failure will ensue. The negatives treated thus should always be printed in the shade—a powerful light would produce an objectionable black halo round the object. All objects which have regular outlines should be thus treated if necessary.

The *Arachnoidiscus* figured below had an exposure of fifteen minutes, with Swift's low angle $\frac{1}{8}$ -inch eye-piece and small microscope lamp. This exposure brought out the diatom sharply and with due printing



ARACHNOIDISCUS INDICUS X 300.

density, but the background was weak, and would have printed in with a most objectionable blackness had not the plan of "painting out" been practiced.

Parts which come out insufficiently dense may be strengthened on the film side of the negative with a soft blacklead pencil. This is best done after the negative has been varnished, using a little turpentine to roughen the part to which the pencil is to be applied.

Local reduction has often to be effected, and can easily be done by using the ferricy-

anide reducer given above. Wet the negative thoroughly; when the excess of water has drained off, dip a fine brush in the solution and apply to the over-dense parts. As each dense place is reduced, dip the negative in water to stop the reducing action and proceed with the next part.

It will often be found that, no matter what skill may be expended on the negative in strengthening the weak parts and reducing the dense ones, it is impossible to get a harmonious print. Some parts will print in strongly long before other parts are done,

and no choice seems to be left but to under-print some portions, and over-print others. In this case, good prints may generally be obtained by the judicious application of cotton-wool. When the quick printing portions are done, cover them with cotton-wool, place the printing-frame in the sun, and print in the denser parts as quickly as possible. In the finished print there should be no mark left by the wool, but all

should appear as if printed in at the same time. The writer once photographed a section—transverse—of hazel, which was thicker one side than the other. As the negative showed splendid detail he did not like to destroy it, but made use of cotton-wool, covering the weak part, corresponding to the thicker side of the section, with cotton-wool as soon as sufficiently printed and leaving the dense part, which corresponded



HEAD AND JAWS, GARDEN SPIDER.

to the thinner side, to print further in a strong light. In the finished print there was not the slightest indication of the unequal density of the negative.

Very dense negatives should always be printed in strong sunlight; but as such negatives always give harsh prints, they should always be reduced to a proper density by the ferricyanide reducer. Some, however, are not injured by excessive density. The density that would ruin a portrait or landscape negative may pass unnoticed in a photo-

to-micrograph, or, perhaps, be even an improvement. The chief objection to dense photo-micrographs is that they print very slowly, but in the majority of cases this will be no serious defect. The figure of a spider's head, given above, is from a very dense negative, which prints very slowly, but otherwise is satisfactory.

Thin delicate negatives should be printed in the shade. The application of matt-varnish or tissue paper to the back of the negative will frequently improve the quality of

the print. As a rule, all negatives should be printed somewhat deeper than is required in the finished picture.

For toning the prints on ready-sensitized paper, the borax, or tungstate toning baths will be found the best. The formula for the borax bath is as follows:

Solution of borax, . . . 8 ounces.

Solution of gold chloride, . 1 ounce.

The borax solution is made by dissolving 1 ounce of borax in 80 ounces of water. For the gold solution break a 15-grain tube of chloride of gold in a bottle, and add 15 ounces of water. Each ounce of water will contain 1 grain of chloride of gold.

For photo micrographs which look best toned a black tint, the tungstate bath is very suitable. The formula is as follows:

Chloride of gold, . . . 1 grain.

Tungstate of soda, . . . 20 grains.

Boiling water, 8 ounces.

To be used when cold.

Many other toning formulæ are used, but the writer has found those given above answer best the requirements of the photo-micrographer.

Before toning, the prints must be washed, either in running water or in several changes of water, to remove all traces of free silver nitrate. A quarter of an hour's washing is not too long. The toning dish should be a large shallow dish of ebonite or porcelain, capable of holding several prints *side by side*—not over each other in layers. Place the prints in the toning bath, and gently rock the dish. They will gradually change color, and when they become of the exact color required, remove them to a basin of clean water.

When all are toned, and *when all the dishes and solutions used in toning are put away*, to avoid all possible contamination by the hyposulphite of soda the prints are transferred to the fixing bath:

Hyposulphite of soda, . 4 ounces.

Water, 20 "

The fixing solution should be prepared shortly before use, and one dram of liquor

ammonia added to each pint, to neutralize the acidity of the hyposulphite. If the ammonia be not added, the prints, after fixing frequently appear of a sickly yellow, instead of a good purple or black.

The prints should remain in the fixing-bath from ten to fifteen minutes, and the dish should be rocked all the time to prevent the prints sticking together. They are next transferred to a basin or tub, and washed for two hours in running water. After this they may be placed between sheets of clean blotting-paper. When the excess of water has been absorbed, they should be ironed between dry blotting-paper until quite dry, when a further ironing on the face and back of the print with a very hot box-iron will improve its appearance. If the photo-micrographer have a rolling press, the ironing may be omitted.

The writer has a frame of prints treated as above, which has been exposed to damp and strong sunlight during three years in a glass-roofed hall, yet no trace of fading can be detected in any one of the prints.

Some subjects, such as diatoms, have a far more delicate and natural appearance if enamelled, either with plain collodion or collodion and gelatine. Full details of this simple process will be found in "Enamelling and Retouching" and "Silver Printing" published by Messrs. Piper & Carter. The photo-micrographer who wishes to excel in his art will find both works simply invaluable.

Our next three or four lessons will be devoted to the consideration of "Preparing Objects specially for Photo micrography."

LESSON VIII.—PREPARING OBJECTS FOR PHOTOGRAPHY.

Many microscopic objects are totally unfit for photo-micrography, as the beginner will soon discover if he attempt to photograph indiscriminately the objects in his collection. It does not follow, because an object looks very beautiful under the microscope, that it will yield even a passable photograph. It may look all that can be desired on the stage of the microscope; all its different parts may be defined clearly

with diffused light, yet its color, or the strong contrast of one part with another, may be such as to render a photograph of it quite impossible. Take, for instance, an object mentioned in our first lesson, the tongue or proboscis of a fly; satisfactory photographs of this object are not common, simply because they have been taken from the specimens usually met with in collections which have been prepared to give the best effect when seen through the microscope, where the strong contrast in depth of color between the lobes of the ligula and the thick portion of the maxillæ and maxillary palpi is no defect, but positively an advantage. When such a specimen is photographed, its unfitness is clearly seen; the thin, transparent lobes are usually much over-exposed long before the darker parts of the ligula have received their proper amount of light; in short, no exposure will suit this object as a whole. It is true a sort of makeshift may be employed, and fair results gained, by shading the transparent parts during exposure, keeping the shade in gentle motion all the time, during half or three-fourths of the exposure, when the whole may be exposed. It is far more satisfactory, however, either to select one of the tongues from a large number, or prepare one specially, so as to subdue these undesirable contrasts, and bring the whole object more into harmony as regards density.

The beginner in photo-micrography is strongly advised to make his own microscopic preparations. A microscope can never be much more than a pleasant toy if its possessor rely wholly on purchased slides. To own even a moderate collection of slides prepared by the professional mounter will cost a large sum of money, and when these have been examined a few times, their interest is gone, and the microscope is laid aside for want of objects to examine. But when the student prepares his own objects, his microscope becomes to him a continual source of pleasure and instruction. His slides, in the majority of cases, may not be equal to those professionally prepared, and they will certainly lack that

exquisite finish which constant practice in their preparation alone can give; but for the purpose of study, and especially for photo micrography, they may be equal to, or even better than, anything that can be purchased from the optician. Then, with practice, the student will so far improve that he will find his own preparations so much better for his special purpose, that he will rarely visit the optician's shop for slides, unless it be to purchase some object that cannot be produced elsewhere, or one which may be beyond his own powers to prepare. That there are such objects, it cannot be denied; and we may perhaps place anatomical preparations in the list of objects better left to the experience and skill of the professional preparer. As the student will not require his objects to be mounted in fancy style, he may prepare slides of such diatoms as he can find in his walks, or obtain by exchange, small as these objects are, purchasing only the rarer forms, or such as are prepared especially as test-objects. Practice in preparing and photographing minute objects, like diatoms, is not only desirable, but necessary, to give the beginner complete command over his microscope and camera.

The apparatus required in the preparation of microscopic objects is neither cumbersome nor costly. The following list includes most of what the beginner will require: A spirit lamp; needles mounted in wooden handles; glass slides, 3 in. by 1 in. (these should be of plate-glass with ground edges); circles and squares of thin cover-glass, the thinner the better; solution of potash, commonly called liquor potassæ; methylated spirits; spirits of turpentine; some pure benzole, not benzoline; nitric, sulphuric, and hydrochloric acids; chlorate of potash; a bottle of balsam, or balsam and benzole; glycerine; gelatine; fine and coarse emery; a glass plate (preferably *plate glass*) about a foot square, and one of cast iron the same size, for grinding down sections of horn, bone, or rocks; a pair of scissors; a sharp knife; a pair of forceps; and a dozen brass clips for holding the covers on the slides, will also be required.

It is best to keep the balsam in a bottle fitted with a wooden stopper, through which a glass rod may be passed. The end of the rod may be kept above the balsam when not in use. When it is required to take some balsam out, the rod can easily be pushed down until it just dips below the surface, and a small quantity taken out without soiling the neck of the jar. Corks should not be used, as they are apt to stick fast, and, by crumbling away, fill the balsam with small fragments which are difficult to remove. By keeping the glass rod always in the bottle, it will remain clean, which would not be the case where it kept elsewhere; and the learner will soon find that cleanliness is absolutely necessary in microscopic work.

Newly purchased slides and covers are always dirty. Water will not always effectually cleanse them; they should therefore be washed in a solution of caustic potash, ammonia or soda. This will free them from impurities; but the slides should afterwards be well rinsed in pure water, or some of the alkali will remain on the glass, and prove as great a hindrance as the dirt.

Microscopic objects are mounted in three different ways: 1. Dry. 2. In a gum, such as balsam or dammar. 3. In some fluid such as water, glycerine, or alcohol. Dry-mounted objects being usually opaque, are not well suited for photography, unless the operator has more than common dexterity in the management of reflected light. In the case of very transparent objects, however, such as diatoms, dry mounting is far the best, as the use of balsam or glycerine does much to obliterate fine markings, on which the interest of the object, perhaps, entirely depends. Balsam or dammar will most generally be used as the mounting medium, as these gums render an object mounted in them more transparent, and can be used in most cases where they exercise no solvent action on the preparation. Insect preparations, vegetable tissues, rock sections, crystals of various salts, are, as a rule, photographed to best advantage when mounted in balsam.

As insect preparations are of perhaps

more general interest than any other, and are more easily photographed, we shall treat of preparing these objects for photography in our next lesson.

LESSON IX.—PREPARING ENTOMOLOGICAL SLIDES.

A glance at the catalogues of the professional preparers will show how popular are insect preparations. Nor is this surprising.

The marvellous beauty of form, the gorgeous colors, the elaborate workmanship displayed in the construction of their various organs, together with the minute size of many of the insect tribe, all render them fit objects for microscopic study. Many of their beauties are apparent to the unaided eye, but under the microscope they are increased tenfold; while others alone reveal themselves to the scrutiny of the magic tube. But for it, the delicate mosaic of the butterfly's wing, the mysteries of the gem-spangled elytra of the diamond beetle, the myriad-faceted eye common to the whole insect world, and all the wonders of their internal structure, would remain hidden to us.

As insects vary so much in size, colors, and texture, the modes of preparing them for photography must also vary to suit the subject under treatment.

I. Opaque Mounting.—This method is alone available in some cases, as the application of balsam or any medium would not only diminish the beauty of the specimen, but often prove destructive in effect. Such objects as scales, such as those of butterflies, the Podura and Lepisma, as well as some wings which are very transparent, as well as small insects like the Tingis and Thrips, which can be successfully photographed by reflected light, should be mounted dry. In the case of small flat objects, as scales, no cell will be required; all that is necessary is to place the scale in position on the slide, and cement a thin cover over it. Larger objects will require a cell, which, for photography, had better be of glass. Glass cells are sold at a cheap rate, look well, and have the advantage of allowing light to pass through their sides, which is often de-

siable. They can easily be manufactured at home by anyone who has a little skill, by cutting rings from glass tubing with a sharp flat file. Various cements may be used for attaching the cell to the glass slip; marine glue is the most trustworthy, but is somewhat difficult to manage, as it requires a strong heat to melt it. Gold-size, when good, is equally reliable, but the various cements which have been used of late years for mending broken china and glass, such as coaguline, appear to be quite satisfactory, and being colorless, look best when used with glass cells.

2. Mounting in Balsam.—Whole insects are usually prepared and mounted in the following way: Having killed the insect, either by means of the cyanide bottle, or by immersion in spirits, it is set out carefully between two glass slides, which are tied together and put in a strong solution of potash—caustic potash one ounce, water twenty ounces. Here it must remain for some time, according to its color and texture; but a frequent examination of the specimen is necessary, as some insects dissolve into a jelly if kept in potash too long. One or two days will suffice for most specimens, but others will take longer. When it becomes sufficiently soft, it is taken out of the potash, placed in a saucer of pure water, and gently pressed with a soft brush until the contents of the thorax and abdomen are expelled. It must then be washed with fresh water until quite clean, when it must again be set out on a slide in the position which it is finally to occupy, covered with a square of thin glass, and tied down with thread. Here the treatment may vary. The older method was to keep the slide in a warm place, under cover, until the preparation became quite dry, and then immerse it in turpentine.

The objection to this plan was that the insect became full of air, which it is almost impossible to expel, unless by the aid of an air-pump. The better method is, to drain all the water from the insect after washing, using blotting paper if necessary, and then immerse it in alcohol and water for about a day, and after that in pure methylated spirit

to displace all the water. A second dose of pure spirit may be necessary in some cases. The whole of the water will thus be removed by the spirit, which will also render the preparation so firm that, on the application of the balsam, it will not alter from the position in which it was set. When quite free from moisture a few days' soaking in turpentine will give most specimens the necessary transparency. Some insects and parts of insects may, however, require to be left in turpentine for several weeks before they are fit to mount.

The tissues of some dark-colored insects are best treated with some bleaching agent immediately after their removal from the potash solution: one of the best is as follows:

Hydrochloric acid,	10 or 12 drops.
Chlorate of potash,	1/2 dram.
Water,	1 ounce.

This will remove the objectionable strong browns and yellows of the chitinous portions, which are so fatal to obtaining a good photograph. By examining the object occasionally, the right amount of transparency will be gained, but it is best not to let preparations remain too long in the bleaching solution, because if too transparent they will be as difficult to photograph as if too opaque. The writer recently photographed two splendid fly's tongues, or ligulae, specially prepared by Topping. These were selected out of seventy-two similar preparations, but while both were perfection as microscopic objects, or for exhibition in the lantern microscope, only one was fit for photography. The other had been bleached too much, and was too thin to give a satisfactory photograph.

When the necessary transparency has been attained, and after the object has been successively treated with alcohol and turpentine, it is ready for mounting. A solution of balsam in benzole is better than pure balsam in many ways. The solution may be prepared by "baking" pure balsam in a slow oven until it becomes quite hard on cooling, and then dissolving in benzole, or may be purchased at the shop of any opti-

cian. The insect, or part of one, is removed from the turpentine and drained, placed in position on a slide, a cover-glass placed over it, and a small quantity of the balsam solution applied to the side, when it will be drawn under by capillary attraction.

By a little care, air-bubbles may be entirely avoided. The slide is then put aside until the balsam has become quite hard, when it may be cleaned for the cabinet, and ornamented with rings of colored varnish, as the mounter's taste may dictate.

Of late years many microscopists have objected to the "squashing" process usually employed in mounting insects, as, in many cases, it deforms and distorts the preparation almost beyond recognition; and now many amateur and professional preparers mount insects without pressure, first gaining the necessary transparency by prolonged immersion in turpentine, and finally mounting with balsam in a cell. Objects thus mounted are very beautiful, especially when illuminated with the paraboloid or spot-lens, but are somewhat difficult subjects for photography, unless a very low power, such as a five-inch, four-inch, or three-inch be employed, as great penetration is required.

It is best, when engaged in mounting insects, specially for photography, not to mount indiscriminately any pretty object, but to set up a type series, to illustrate the class *Insecta*, which, when photographed, would have a real scientific value. Something after the following style might be attempted:

1. Coleoptera.—Many of the smaller species can be set up whole, after bleaching in the chlorate of potash mixture. A few feet may also be mounted; the paddle-foot of *Dyticus*, the broad-padded foot of *Timarchus*, and the type-foot of *Carabus*. Some of the antennæ, as those of *Melolontha*, are also well worth mounting and photographing.

2. Dermaptera (the earwigs).—A specimen may be mounted whole for a five-inch objective; if possible, with the wings expanded. This subject will not require more than a few hours' treatment with potash.

3. Orthoptera (the cockroach).—*Blatta Orientalis* is a good type, although not a true English insect. Almost colorless specimens may be found in kitchens which these creatures haunt. These will require no preliminary bleaching.

4. Thysanoptera.—The diminutive insects so abundant and so troublesome in hot summers— insects which will persist in crawling over one's face, and into one's mouth and eyes, which swarm everywhere and on everything—constitute this order. One of the largest, *Phlaeothrips coriacea*, measuring about $\frac{1}{4}$ of an inch in length may be set up whole in balsam.

5. Neuroptera.—A portion of the large faceted eye of the dragon-fly may be mounted flat on a slide in balsam, and will form a very instructive photograph.

6. Trichoptera.—The larva of the caddis-fly may easily be prepared. The internal parts must be removed, when, after washing and treatment with turpentine, it is ready for mounting. The mature caddis-fly may be set up whole.

7. Hymenoptera (bees and wasps).—The wings, showing attaching hooklets, may be mounted dry or in balsam. The feet will require to be bleached strongly, as most of the *Hymenoptera* are strongly colored. The modified ovipositor, called a "sting," should be cut from the insect carefully, so as to have the poison bag attached. The stings—for there are two—lie enveloped in a case of brown chitine, from which they may be dislodged with a fine needle. The poison-bag, owing to its extreme transparency, must be stained—not with blue, as in many professional preparations, but with brown. Bismarck brown is, perhaps, as good as any. Sufficient stain should be used to give this part as nearly as possible the same color as the stings.

The saw-flies show another modification of—or, rather, addition to—the real ovipositor. This consists of a sawing apparatus, composed of four saws—two small and two large ones, the former fitting into the latter. This object is rather difficult to photograph when set up in balsam, as it becomes too transparent. A well-mounted dry specimen will give more satisfaction.

8. *Lepidoptera* (or butterflies) are interesting from their finely-marked scales, which form tests for low powers. They should be mounted dry.

9. *Homoptera* (frog-hoppers and *aphides*).—The former possess saws, which may be prepared like those of the saw-flies.

10. *Heteroptera* (or bugs).—The "beak" of *Cimex lectularius* and the oar-foot of the water boatman may be mounted in balsam.

11. *Aphaniptera* (or fleas). The insects to be successfully mounted, require a severe treatment with potash, and a long soaking in turpentine. Preliminary bleaching in the hydrochloric acid mixture is, perhaps, best to get rid of the yellow color, which renders them difficult to photograph satisfactorily.

12. *Diptera* (or flies)—The feet of the dark-colored species will require bleaching with chlorate of potash. The "tongues," or *ligulae*, should also be bleached, but *not too much*. The proper way to mount a fly's tongue is to set it up in a shallow cell, *without pressure*. The specimens usually sold, being mounted flat, are distorted, and give an improper idea of the real shape of the organ.

For further information as to dissection, etc., the student is referred to *Practical Microscopy* by Mr. G. E. Davis.

LESSON X.—PREPARING VEGETABLE TISSUES FOR PHOTOGRAPHY.

Dry-mounted vegetable preparations are not of much use to the photo-micrographer, except it be certain scales, such as those of the *Deutzia*, which can be successfully photographed with a low power by reflected light. In most cases the use of a bleaching liquid is necessary to get rid of the coloring matter, which must be removed before the tissues can be set up as transparent objects. The following bleaching liquids may be used: 1, Nitric acid; 2, methylated alcohol; 3, chlorinated soda.

1. Nitric acid must generally be used in a very dilute form, as many vegetable tissues, even those strongly impregnated with silica, are destroyed by it when pure. The

stems of grasses, horsetails, and even leaves, as those of the *Dentzia*, may be bleached by gently heating in very dilute nitric acid. When the object appears sufficiently transparent, it must be well washed in distilled water to remove all trace of the acid, floated on a slide, and dried under cover. If the acid be used too strong, the object is decomposed, while if the washing be imperfect, crystals will form in its substance and render it useless.

2. Soaking in alcohol does very well for many objects, such as cuticles, and thin, semi-transparent leaves. They should be left in alcohol for some hours; and when they have lost most of their chlorophyl the alcohol must be poured off, and some fresh added, until the objects become white. They may now be transferred to benzole or turpentine for some hours, when they are ready for mounting. Boiling in alcohol is hardly advisable, for although it considerably hastens the bleaching, it tends to make all plant-tissues too brittle for mounting.

3. The best mode of bleaching vegetable tissues is by means of chlorinated soda. The solution is prepared as follows: Three or four onnces of good chloride of lime are taken, and put in about a quart of water. Stir the mixture a few times, and allow the sediment to settle; after this the liquid had better be filtered through coarse filter-paper; this is better than pouring the clear liquid off. Next, pour a strong solution of carbonate of soda into the chloride of lime solution, so long as a precipitate takes place, and allow the precipitate to subside. When clear, the solution should be tested with a few more drops of carbonate of soda, to ascertain if all the lime have been precipitated; if not, more should be added, until no lime be left in the solution. Most of the solution, when clear, can be poured off, and must once more be filtered; after which it should be stored in black or dark-colored bottles, and well-corked, since both air and light speedily bring about decomposition.

A series of small glass pots should be provided to bleach the specimens. Shallow pomade pots are very suitable. Before

leaves are immersed in the fluid, it is best to wash them in clean water with a soft brush, since all leaves are more or less covered with fine dust, which will sink into their substance if not removed when they are fresh. When they are quite clean, they may either be put in the bleaching liquid at once, or put between clean blotting-paper to dry. Dried leaves, as a rule, bleach more rapidly than green ones.

When a leaf happens to be more deeply colored than usual, it is a good plan to immerse it in alcohol until most of the color has been removed. This much facilitates the bleaching process. The time which tissues require to be soaked varies considerably. Some becomes translucent in a few hours, while others take many days; others will show green patches which obstinately refuse to be bleached. In this case, remove the leaf, wash it well, and place it in alcohol for some hours. In this way all the chlorophyl will be dissolved out, when the soda solution will complete the processes. Care must be taken not to put too many leaves at a time into one vessel; three or four is the average number.

When properly translucent, the leaves or tissues must be removed from the soda solution, and washed in distilled water, changing the water every few hours. If the tissues do not contain Raphides, the addition of a little hydrochloric or nitric acid to the second or third washing will increase their transparency. *Sulphuric* acid must not be used, or crystals of sulphate of lime, which is only slightly soluble in water and acids, may be formed in the tissues, and cannot be removed.

About twenty-four hours is necessary to properly wash the leaves; less time is not sufficient, and a longer immersion tends to disintegrate delicate tissues. The washing completed, they should be placed in alcohol, in which they must remain for some hours, and afterwards be transferred to turpentine until required for mounting.

The above bleaching process must be applied to sections of wood which are too strongly colored for photography. It is hardly necessary to observe that all sections

which are to be photographed should be of extreme thinness. Many which answer very well for examination under the microscope are far too thick for the photo-micrographer. Light-colored sections, such as those of white pine, require merely saturation with benzole before mounting in the balsam solution. A section of deal, to show the characteristic "discs," should be mounted dry.

Spiral vessels, scalariform tissue, etc., will require but little treatment; the former, after drying and washing in alcohol and benzole, may at once be set up in balsam.

Cuticles may be prepared in the same way. In the case of very transparent tissues, staining will be of great use. Judson's dyes answer very well for this purpose, but all blue stains should be avoided in objects intended for photo-micrography.

Plant-crystals, or raphides, may be prepared either *in situ*, or separately. When mounted *in situ*, bleaching with alcohol is alone admissible. Raphides may be obtained from most plants by laying a leaf or stem on a slide, with the cut end about the middle; a gentle rolling pressure with a pencil will squeeze the juice and raphides out on the glass. Wash with alcohol, pour over a little turpentine, and mount in the usual way.

The following furnish good examples of raphides: duck weed, the onion, the willow-herb, the galium or goose-grass. The large prismatic crystals of the onion or garlic polarize splendidly, and show better in a photograph when polarized light is used. In fact, many objects that are far too transparent to make good photographs can be easily managed by putting on the polariscope. When this is of no use, a piece of fine ground glass, or oiled paper, immediately below the slide will be of great service in softening the light. This will prolong the exposure, but give results that could not otherwise be attained.

For instruction as to staining vegetable tissues, the student is referred to a very valuable and practical paper by Dr. George D. Beatty, which appeared in *Science Gossip* for May, 1876; also to *Practical Microscopy*, Chapter 12.

LESSON XI.—PREPARING SECTIONS OF HARD SUBSTANCES FOR PHOTOGRAPHY.

MANY of the sections of hard substances, such as bone, rock, etc., sold in the shops, are too thick. Those prepared by the best lapidaries cannot be excelled; and if the student can afford to pay the high price charged for making these sections—from 2s. to 2s. 6d. each—he is advised not to undertake the labor and trouble of preparing them himself. For, although the manipulator may be skillful and patient, even when a machine is used, cutting sections of rocks is both tedious and laborious.

There are many excellent machines in the market specially devised for cutting sections; but they are all more or less expensive, and good work may be done by using very simple appliances, which we shall now proceed to mention. In the first place, procure an iron plate, preferably cast iron, about twelve inches square, and as thick as can be obtained. Next, a Water-of-Ayr stone, and one of harder texture, such as a Washita stone. These may be obtained at any tool shop. A Turkey stone is very good for sections of bone. For grinding down rocks, emery of various degrees of fineness will be required—buy one pound of medium coarse, one pound of medium fine, and one pound of flour emery.

To grind down a rock section, proceed as follows. Make a chip with a hammer about one inch square, and not more than one-eighth inch thick. Sedimentary rocks, such as limestones, may be thicker. Rub down the chip with coarse emery and water on the iron plate, until one side is perfectly flat. Remove the scratches by next rubbing the chip on a piece of plate-glass with fine emery, and then polish with water on the Water-of-Ayr stone; when quite smooth, wash it well, and let it dry. Meantime put some old hard balsam on a glass slip and warm it over a lamp until all the more volatile parts of the balsam evaporate, so that, on cooling, it becomes hard and tough. Don't *boil* the balsam, and don't continue the heat too long. When the balsam is properly hard, heat the chip on a metal plate, rub over it a little turpentine,

and remelt the balsam; lower one end of the chip slowly into the balsam, and press it down close to the glass slip. When the balsam is cold, rub down the chip on the iron plate with coarse emery until too thin to bear further friction. Very hard rocks may be brought down to the requisite thinness on the iron plate alone, and will only require a little polishing on a stone to remove the deeper scratches. Sections intended for photography should be cut down to the extreme of thinness, and *all* sections should be cut thin enough to read through when placed on the page of a book. When the section becomes too thin to bear any longer the friction of the coarse emery wash it well, and grind it thinner on the glass plate with fine emery, and finish off on the Water-of-Ayr stone. If the section is strong enough to bear it, it should be removed from the slip on which it has been ground, and mounted on a clean slip. Warm the slide over the lamp sufficiently to melt the balsam, and push the section off with a needle into a cup of turpentine, and wash it carefully with a small, soft brush. Now pour a little balsam and benzole on the clean slip, put the section upon it, add a little more balsam, and cover with a circle or square of thin glass.

Sections of bone or horn must be first cut with a fine saw, and ground down in the same way, only no emery must be used, and the iron plate will not be required, as the Water-of-Ayr and Washita stones will prove sufficient. Before such sections are mounted, they should be soaked for a day or two in balsam and benzole to render them perfectly transparent.

Sections of soft rocks, and sedimentary rocks generally, are prepared and mounted in the same way, only no emery must be used, or it will imbed itself in the section and cause false appearances under the microscope. Most sedimentary rocks can be finished on the Water-of-Ayr stone. Some very friable rocks, or substances such as boiler incrustations, which readily disintegrate on the grinding-stone, must first undergo a preliminary hardening. Two hardening solutions are generally made use

of—balsam and benzole, or a solution of shellac in alcohol. The latter is much the better of the two. The solution should be quite limpid. For soft limestones a soaking of two or three days will be sufficient, but a piece of boiler incrustation will require to be left in the solution for at least a fortnight. When the rock is thoroughly impregnated with the hardening solution, take it out, and put it to dry in a warm place until the solvent has evaporated, leaving the balsam or shellac in the pores quite hard.

Sections of rocks which contain organisms

—such as foraminifera, should not be ground very thin, or most of the fossils will be ground away, leaving the section quite useless as a specimen.

Most thin rock sections photograph better by polarized light, as the structure is thus much better shown. Sedimentary rocks, even white limestones, stop a great deal of light, and will require a long exposure. Such sections are always much improved by a few days' soaking in balsam and benzole, to render them more transparent.



CRYSTALS OF ARSENIC, FROM A DEPOSIT OF .002 GRAIN.

LESSON XII.—PREPARING CRYSTALLIZATIONS FOR PHOTO-MICROGRAPHY.

Most chemical crystals are mounted in balsam, as they are usually viewed by polarized light; but where this is inapplicable, or when the crystals are soluble in balsam, this medium must not be employed, and the crystals must be simply evaporated from an aqueous or alcoholic solution on a clean glass slide, and covered with a circle of thin glass. The majority of chemical salts are soluble in water, and when typical crystals are not required, the addition of a little

gelatine to the water will usually produce larger, and in some cases more beautiful forms. However, as the genuine typical forms will be generally required in a photograph, it is best to use nothing but distilled water, or pure alcohol, in making up the solutions. To obtain typical crystals, the solutions should not be concentrated, but normal, and the evaporation of the salt should not be accelerated by too much heat. As a general rule, the most perfectly formed crystals are obtained by very slow evaporation in a cool place. Many salts, if evaporated in a hot room, or over a lamp, give

nothing but a confused mass of amorphous forms. It is often better, instead of applying heat to a drop of the solution on a glass slide, to make a hot solution in a test tube, and evaporate a few drops slowly on the glass slip. Arborescent crystals, no matter how beautiful in themselves, are a great nuisance when the student wishes to prepare the typical forms for photography, and they may be avoided by allowing the solution to crystallize out slowly. Potassium bichromate, if crystallized rapidly, either over the

lamp or from a hot solution, usually gives arborescent forms; but when evaporated in the cold, the characteristic prismatic crystals are obtained. All salts crystallized from an alcoholic solution should, as a general rule, be evaporated in the cold. As an example of this, magnesium platino-cyanide, when evaporated from an alcoholic solution rapidly, gives only an amorphous red mass. To obtain the prismatic crystals arranged in rosettes, the solution must be evaporated slowly in a cool room free from draughts.



CRYSTALS OF ARSENIC, FROM A DEPOSIT OF '001 GRAIN.

White arsenic, As_2O_3 , may be obtained either from its aqueous solution, or by sublimation. The latter mode gives more brilliant and regular crystals, but is more troublesome. A small portion of arsenic should be put in a short test-tube about one inch long, and a glass slide laid over the top. On applying heat, the crystals will form on the sides of the tube and on the slide. By a little careful manipulation with the spirit lamp, the bulk of the crystals may be driven from the sides of the tube and made to crystallize on the glass slip. They should be covered with a circle of thin glass

—no balsam must be used, or they become too transparent to photograph. The preceding cuts, photographed from slides of '001 grain, and '002 grain of arsenic, show the general form of the crystals.

Strychnine is very insoluble in water, so it should be crystallized from its dilute alcoholic solution. The form of the crystals is the octohedron, or square prism—usually the latter. As it dissolves in balsam it should be mounted dry. With a solution of picric acid strychnine yields hook-like crystals, which may easily be photographed with a low power.

Brucia must be crystallized from alcohol. The crystals are oblique rhombic prisms. It dissolves in balsam rather rapidly, so should be either set up dry or in castor oil.

Atropine, caffeine, and narcotine crystallize in needles. The former must be mounted dry. Morphia, and morphia chloride, sulphate, and acetate may be crystallized either from water or alcohol, and mounted in balsam.

Quinine sulphate gives a profusion of silky needles from a dilute alcoholic solution. Owing to their delicacy they are difficult to preserve, but may be mounted in dilute balsam and benzole.

Sulphur must be dissolved in carbon bisulphide. The best crystals are obtained in winter; but at all times of the year the solution must be evaporated in a room quite free from draughts, and as cool as possible. These crystals must be photographed by reflected light with a low power. Salicine is a very favorite microscopic object; but the splendid discs usually seen on slides are only modifications of the typical acicular crystals. The real forms are best obtained from a dilute aqueous solution, which may be hot. If a little gelatine be added to the solution, delicate discs form on crystallization, which are seen to consist of needles radiating from a common centre. Fusion of the dry salt gives only coarse discs, but if a concentrated

aqueous solution be made, and evaporated over a lamp until fusion just commences very delicate discs of a larger size may be obtained. One method of obtaining fine discs is to put a solution of salicine in gelatine on a glass slip. Warm the slip over the lamp for a few moments, and then pour the solution off; enough will be left on the slide to form a thin film. The film is then pricked in several places with a fine needle, and immediately crystallization commences, from each prick as a centre, and goes on all over the slide. The whole is at once covered with balsam and benzole, and a thin glass square gently pressed on. If not covered at once, the crystals become opaque.

Santonine and phloridzine are crystallized from an alcoholic solution, and may be preserved in balsam.

Here our Lessons in "Photo-micrography" are brought to a close. The student must once more be reminded that skill in manipulation of the microscope will not by itself produce the best results. There must be not only expertness in each photographic operation, but an intelligent understanding of the *why* of each process. Photography as a science must be studied by itself, and for itself; for it is only when an intelligent understanding, both of microscopy and photography, is gained, that photo-micrography becomes worth pursuing.

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